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LANL Measurements Verification Acceptance Criteria

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LANL Measurements Verification Acceptance Criteria



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Abstract

The possibility of SNM diversion/theft is a major concern to organizations charged with control of Special Nuclear Material (SNM). Verification measurements are used to aid in the detection of SNM losses. The acceptance/rejection criteria for verification measurements are dependent on the facility-specific processes, the knowledge of the measured item, and the measurement technique applied.

This paper will discuss some of the LANL measurement control steps and criteria applied for the acceptance of a verification measurement. The process involves interaction among the facility operations personnel, the subject matter experts of a specific instrument/technique, the process knowledge on the matrix of the measured item, and the measurement-specific precision and accuracy values.

By providing an introduction to a site-specific application of measurement verification acceptance criteria, safeguards, material custodians, and SNM measurement professionals are assisted in understanding the acceptance/rejection process for measurements and their contribution of the process to the detection of SNM diversion.

Introduction

LANL has employed various acceptance/rejection criteria (for simplification we shall abbreviate this as ARC) for verification measurements, specifically between 1999 and 2001. During this time period a campaign to verify all non-TID'd (Tamper Indicating Devices) items at LANL was active, and contributed to the development of this ARC. The intention being to validate existing book values, TID the item, and update the inventory database.

The application of LANL ARC is not meant to be an all-inclusive authority on how all facilities go about accepting their verification measurements. It is intended to present a real life day-to-day approach given pressing schedules, funding constraints, equipment/standards availability, and a graded safeguards approach. The ARC revealed the evolutionary nature of the process as each individual case was addressed. The criteria are based on technical and administrative judgment with the intent on exercising a graded safeguard approach, by applying the most rigor and discipline to that material which is most attractive.

Problem Statement

The issue of what constitutes a valid, and technically supportable verification measurement is not new to the nuclear material measurement community. It has inherent controversy, as each respective organization seeks to interpret and implement their objectives. At LANL, the MC&A (Measurement Control & Accountability) team, supported by other laboratory subject matter experts is tasked with the final oversight responsibility in releasing these measurements as they relate specifically to physical inventories, DOE endorsed campaigns, and off-site shipments and receipts. Unique resolutions to specific measurement problems are dynamic and continue to evolve with time. If this paper clearly documents how verification measurements have been addressed at LANL in recent times, granted the dynamic nature of the process, then my objective is served.

Definitions

Accountability measurement:	A quantitative measurement using an approved non-destructive assay (NDA) or destructive assay (DA) techniques for determining nuclear material content and are the basis for establishing or changing a book value.
Confirmation measurement:	A measurement to test whether an attribute or characteristic of the nuclear material in the item is consistent with the expected attribute or characteristic of the material. Typical confirmation measurement methods include balances, GN4/Ranger gamma neutron measurement, and spectral identification using the NOMAD.
Double Confirmation:	Two independent confirmation measurements, e.g. balance and GN-4 gamma neutron measurements.
Graded Safeguards:	A system designed to provide varying degrees of physical protection, accountability, and control to different quantity and type of special nuclear material. The more attractive the material is to malevolent acts the more stringent the controls.
Three Sigma:	Instrument measurement control limit defined as an alarm. Also used to determine if an item has failed the PAV acceptance criteria.
Two Sigma:	Instrument measurement control limit defined as a warning.

Verification measurement:

A quantitative measurement using approved non-destructive assay (NDA) or destructive assay (DA) techniques to verify an existing accountability value.

Measurement Control

Before measuring an unknown item, standard calibration checks are performed to ensure an instrument is operating within its control limits. The control limits provide the operator with a pass/fail indicator immediately upon entry of the standard measurement data into our Materials Accounting Safeguards System (MASS) database. MASS automatically places an instrument out-of-service when a control check exceeds our alarm limit at three-sigma. If it exceeds the two sigma (warning) limit, MASS places the instrument in a non-availability state until additional measurements are shown to pass at two sigma. In either case, data entry for the unknown is not allowed by MASS until Operations and MC&A resolve the out of control condition.

Verification Measurement Criteria

Our initial verification acceptance criteria involved computing a combined uncertainty bound for both accountability and verification measurements at the approximate 95% confidence level.

LANL defines the 95% confidence bound for a single measurement as:

$X(\beta + 2\sigma)$, where X is the measured value, β is the percent accuracy value for the measurement and σ is the percent precision for the measurement as defined in the Precision and Accuracy Values (PAVs).

To establish appropriate PAVs for each measurement technique, LANL maintains a re-measurement database. The PAVs are derived from the re-measurement database and reflect the instrument contribution of counting statistics and the contributions of error caused by matrix variations not reflected in the standards used for instrument control and calibration. The accuracy of the calculated PAV depends upon the number of data points available. The PAVs are not static values, but are updated as data is accumulated.

A verification measurement validates the original accountability measurement when

$$|X_1 - X_2| < |\beta_1 X_1| + |\beta_2 X_2| + 2\sqrt{(\sigma_1 X_1)^2 + (\sigma_2 X_2)^2}$$

where:

X_1 = technique 1 measured value (accountability measured value)

X_2 = technique 2 measured value (verification measurement value)

β_1 = percent bias value for technique 1

β_2 = percent bias value for technique 2

σ_1 = percent precision value for technique 1

σ_2 = percent precision value for technique 2

In the event a measurement fails these initial criteria, the inventory history of the item is checked, including previous measurement data, to determine if an error occurred in the past. Material that fails to meet verification measurement criteria cannot be used until the discrepancy is resolved¹. If the investigation cannot resolve the failed PAV acceptance rejection criteria, the Verification Measurement Evaluation Process decision tree is invoked. See attachment 1.

In the final stages of the decision tree, Safeguards management may rely upon alternative justifications for a verification measurement to be found acceptable. Several administratively imposed graded safeguard criteria evolved for deeming a verification measurement acceptable which have included:

1. Item failed the warning criteria at 2 sigma, but passed the alarm criteria at 3 sigma. This was in correlation to LANL's measurement control program that would place an instrument out of service upon failing a 3-sigma control check.
2. Items original book value (isotopic in the case of uranium) is less than 50 grams. An administratively placed cutoff value that was assumed to be less than safeguard significant.
3. The difference between the original book and verification value is less than 10% of a category IV quantity for the items attractiveness level. Category quantities for given attractiveness levels are quoted from DOE M 474.1-1. See Attachment II.
4. Item was originally included in poorly measured population. This population of items has accountability "book" values that are known to be not amenable to measurement for several possible reasons (e.g. isotopic mixtures, physical size, and unavailability of representative standards, etc), and therefore deemed likely to fail a verification measurement.
5. Items MT are 72 (²³³U) and successful double confirmation measurements were determined to qualify as verification. ²³³U standards cannot be safely fabricated and consequently verification measurements techniques are unavailable.
6. Item was processed or shipped off to another facility (TA-55) or offsite. This criterion refers largely to the verification campaign (SSG) of items originally selected but was not available when actual measurements begun. Processed material would require new accountability measurements.
7. Items MT are 83 (Pu-238) and have been exempted from verification measurements due to safety concerns (e.g. ALARA concerns, container integrity, etc).
8. Monte Carlo Nuclear Program (MCNP) calculations by Shuffler SME² for specified items where material matrix was not represented in limited standards available, producing a bias correction factor to correct for impurities e.g., graphite matrix mixture, polyethylene in container packing material, etc.

¹ Materials Control & Accountability Plan (4/27/00)

² Phillip M. Rinard, NIS-5; Bias Corrections for "STD" and "CAL" Inventory Items; February 14, 2001

9. In the event that material being measured is slated for off-site shipment and the receiving facility has agreed upon the quality of the verification measurement, irrespective of differences due to lack of ideal standards, measurement technique limitations, etc.
10. During a bimonthly physical inventory a double confirmatory measurement qualifies as a verification for metals only. A calibrated balance measurement, in combination with known material weight factor and isotopic confirmation using GN4 is adequate.

Conclusion

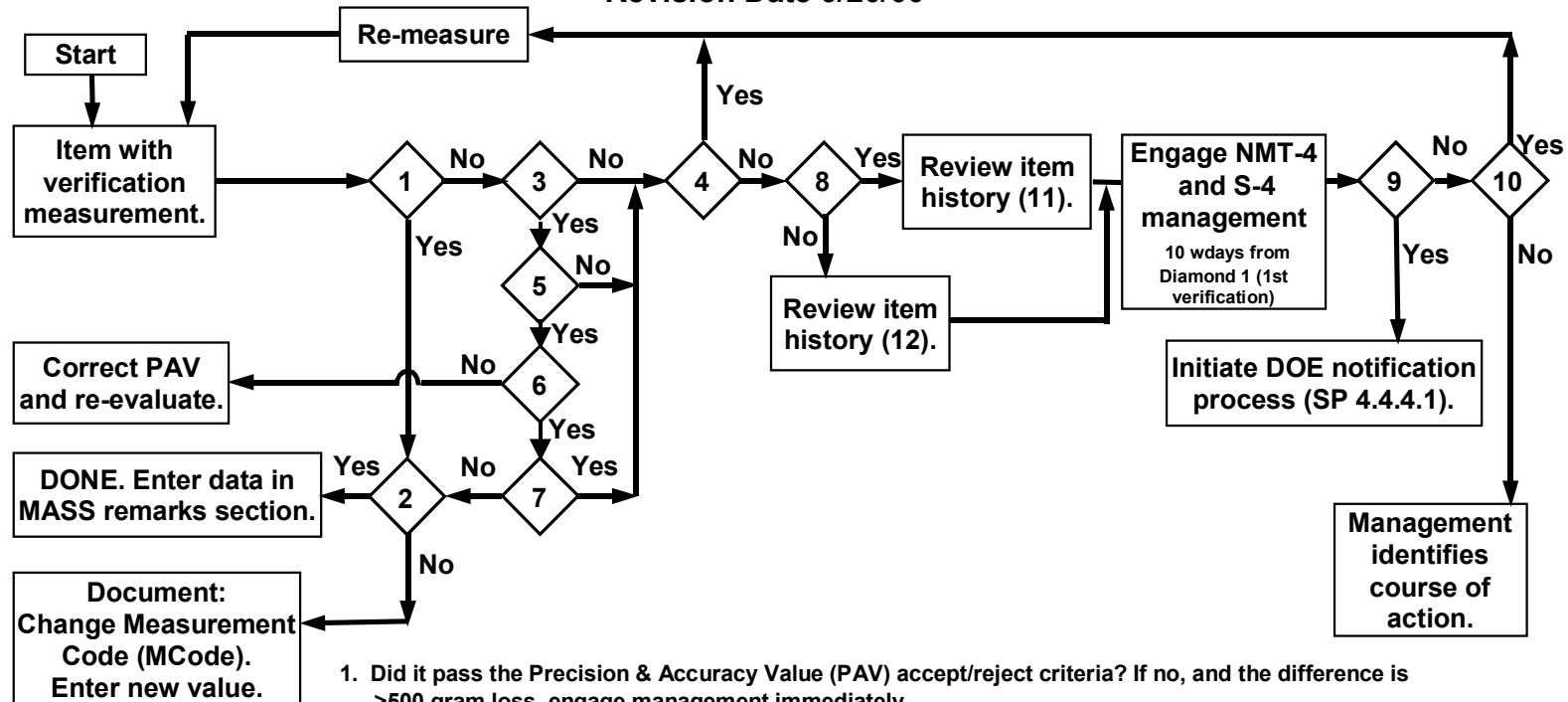
Arriving at a common agreement as to what is an acceptable verification measurement was found to be an iterative and evolving process. As one looks closer at an item's specific matrix, geometry, and history, as well as the limitations of an instrument and available appropriate standards, administrative solutions became inevitable. A graded safeguards approach was then applied and based on factors such as attractiveness of material, realistic potential for diversion of material, shipper/receiver agreements on acceptability of precision, as well as supportable technical arguments presented by subject matter experts on the given material and measurement techniques.

The overall goal of verifying an item against its original booked value was accomplished by exhausting all available empirical and analytical techniques in combination with an understanding of the comprehensive safeguards and security controls in place. The utmost concern for the possibility of SNM diversion/theft was kept paramount at all times.

ATTACHMENT 1

Verification Measurement Evaluation Process

Revision Date 9/20/00



1. Did it pass the Precision & Accuracy Value (PAV) accept/reject criteria? If no, and the difference is >500 gram loss, engage management immediately.
2. Is the original measurement better and is documentation available?
3. Was appropriate measurement method used for verification? (Was item IVP, PM, or WM? Was geometry or matrix a factor? Did it pass 3-Sigma?)
4. Do we re-measure? Consider a different measurement method.
5. Is book value supported?
6. Was correct PAV used?
7. Is the difference of safeguards significance (>10% of a category IV quantity for item's attractiveness level)?
8. Is the difference a loss?
9. Is DOE notification required?
10. Do we re-measure using a more costly or exotic method?
11. Treat as potentially missing material. Immediately call on historical SMEs.
12. Treat as a potential diversion path. Call on historical SMEs.

Attachment II, Graded Safeguards.

	Attractiveness Level	Pu/U-233 Category (quantities in kgs)				Contained U-235 Category (quantities in kgs)				All E Materials Category IV
		I	II	III	IV ¹	I	II	III	IV ¹	
WEAPONS Assembled weapons and test devices	A	All	N/A	N/A	N/A	All	N/A	N/A	N/A	
PURE PRODUCTS Pis, major components, button ingots, recastable metal, directly convertible materials	B	≥ 2	$\geq 0.4 < 2$	$\geq 0.2 < 0.4$	< 0.2	≥ 5	$\geq 1 < 5$	$\geq 0.4 < 1$	< 0.4	
HIGH-GRADE MATERIALS Carbides, oxides, solutions ($\geq 25 \text{ g/L}$) nitrates, etc., fuel elements and assemblies, alloys and mixtures, UF_4 or UF_6 ($\geq 50\%$ enriched)	C	≥ 6	$\geq 2 < 6$	$\geq 0.4 < 2$	< 0.4	≥ 20	$\geq 6 < 20$	$\geq 2 < 6$	< 2	
LOW-GRADE MATERIALS Solutions (1 to 25 g/L), process residues requiring extensive reprocessing, moderately irradiated material, Pu-238 (except waste), UF_4 or UF_6 ($\geq 20\% < 50\%$ enriched)	D	N/A	≥ 16	$\geq 3 < 16$	< 3	N/A	≥ 50	$\geq 8 < 50$	< 8	
ALL OTHER MATERIALS Highly irradiated forms, solutions ($< 1 \text{ g/L}$), uranium containing $< 20\%$ U-235 (any form, any quantity)	E									Reportable Quantities

¹ The lower limit for Category IV is equal to reportable quantities in this Manual.